Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	IB Docket No. 11-109
Comment Sought on Ligado's	)	
Modification Applications	)	
	)	
To: The Commission	)	

FURTHER REPLY COMMENTS OF LIGADO NETWORKS LLC

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I. INTRODUCTION AND SUMMARY

The Commission has rightly acknowledged in a number of proceedings the importance and urgency of making additional spectrum available for 5G and next generation wireless services.[1] Chairman Wheeler recently identified 5G as "a national priority" that can be achieved with a "spectrum trifecta" that includes mid-band spectrum.[2] Ligado's Modification Applications[3] present one of the best opportunities available for making key mid-band spectrum available to serve this goal, as other commenters note.

Moreover, the record in this proceeding demonstrates that:

- Terrestrial operations in accordance with the license modifications sought by leading GPS firms and Ligado will cause no actual harm to GPS consumers, and industrial (high precision) GPS devices are either unaffected or can be remedied to ensure no impact. No commenter presented any technical evidence rebutting these conclusions,

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[1] *See*, *e.g.*, *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Report & Order, 29 FCC Rcd. 6567, 6570 (2014). *See also* Prepared Remarks of FCC Chairman Tom Wheeler, "The Future of Wireless: A Vision for U.S. Leadership in a 5G World," June 20, 2016, *available at* http://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0620/DOC-339920A1.pdf ("Wheeler 5G Remarks").

[2] Wheeler 5G Remarks, *supra* n.1, at 3.

[3] *See* IBFS File Nos. SAT-MOD-20151231-00090, SAT-MOD-20151231-00091, and SES-MOD-20151231-00981 (collectively, "Modification Applications"). The Modification Applications include a "Description of Proposed Modification and Public Interest Statement" (Modification Applications, Description of Proposed Modification).

which were reached by expert engineering firm Roberson and Associates ("RAA") after extensive testing. In addition, the Modification Applications offer comprehensive protection for aviation interests, as Ligado further explained in its June 6 Reply Comments.[4]

- Grant of the Modification Applications will produce tremendous net benefits to the American economy, as demonstrated by the Brattle Group's expert economic analysis.[5] No commenter has challenged these conclusions.

- There is no persuasive evidence in the record supporting the assertion that a 1 dB degradation in a GPS receiver's carrier-to-noise density ratio (C/N_0) has any relationship to the existence of harmful interference affecting the receiver's actual performance. Indeed, there is substantial empirical evidence to the contrary. Accordingly, using the 1 dB metric as a basis for restricting Ligado's proposed use of spectrum adjacent to GPS would be arbitrary and capricious.

Three leading GPS companies — Deere & Company, Garmin International, and Trimble — do not object to the grant of the Modification Applications.[6] A few parties have raised certain specialized questions regarding the satellite industry and the industrial GPS device sector, but none of these comments included the kind of specific, technical information about device performance that the Public Notice requested (and that Ligado has submitted). Nonetheless, Ligado remains committed — as it has demonstrated and will continue to demonstrate — to studying and resolving in a reasonable manner the remaining issues identified by interested parties.

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[4] *See* Reply Comments of Ligado Networks LLC, IB Docket No. 11-109, at 4-8 (filed June 6, 2016) ("Ligado Reply").

[5] *See generally* Coleman Bazelon, *Putting Spectrum to Work: Sharing Between Ligado Networks and Its GPS Neighbors* (May 23, 2016) (hereinafter, "Bazelon Report").

[6] Specifically, in their respective agreements, Deere and Garmin agreed that they will not object to Ligado's terrestrial deployment in three of the four bands licensed to Ligado — the 1526-1536 MHz, 1627.5-1637.5 MHz, and 1646.5-1656.5 MHz frequency bands — as long as Ligado operates under certain power and OOBE limits. The Garmin agreement does not address potential interference concerns relating to certified aviation devices, which are addressed separately below. Trimble also agreed not to object to Ligado's proposed operations in two of those three bands — the 1627.5-1637.5 MHz and 1646.5-1656.5 MHz frequency bands. Regarding operations in the lower downlink band (1526-1536 MHz), the Trimble agreement allows for further analysis of terrestrial use of that band.

The evidence in the record establishes that the Commission should grant the Modification Applications forthwith. Doing so will add vital greenfield mid-band spectrum for the critical transition to 5G, enabling innovative applications such as IoT, while cementing protections for Deere, Garmin, Trimble, and the entire GPS community.

II. LIGADO'S PROPOSED OPERATING PARAMETERS ENSURE NO IMPACT TO CONSUMER DEVICES AND MEET A VITAL NEED FOR SPECTRUM

A. The Parameters Proposed in the Modification Applications are Compatible with Consumer Devices.

In the Modification Applications, Ligado relinquished its ability to use the 1545-1555 MHz band for terrestrial service, while proposing strict limits on the equivalent isotropically radiated power ("EIRP") and out-of-band-emissions that would be permitted for Ligado's terrestrial operations.[7] The result is that Ligado has agreed to operate at power limits that are lower than its current licenses authorize b*y a factor of 10 times for the downlink and a factor of five times for the uplinks*, and for the first five years, by as much as a factor of 1,250 times for part of the uplink closest to the GPS band.[8] Ligado also has agreed to operate with out-of-band-emission limits that are lower than what is currently authorized by a factor that ranges from 10 times to 800 times from the uplink bands into the GPS spectrum band.[9]

These limits derive in part from the Co-Existence Agreements Ligado reached with each of Deere, Garmin, and Trimble.[10] The test program conducted by RAA confirms what the Co-

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[7] *See* Modification Applications, Description of Proposed Modification at 4-7 (setting forth the particular technical details of the proposal).

[8] Comments of Ligado Networks LLC, IB Docket No. 11-109, at 14 (filed May 23, 2016) ("Ligado Comments").

[9] *Id*. at 14-15.

[10] *See* Letter from Gerard J. Waldron, Counsel to New LightSquared LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 12-340; IB Docket No. 11-109; IBFS File Nos. SAT-MOD-20101118-00239; SAT-MOD-20120928-00160; SAT-MOD-20120928-00161; SES-MOD-20121001-00872; SES-RWL-20110908-01047; SES-MOD-20141030-00835, at 4 (Dec. 8, 2015)

Existence Agreements already demonstrated: "that Ligado's proposed LTE deployment is clearly compatible with existing GPS operations as implemented by leading device manufacturers."[11] Specifically:

- The largest category in the GPS receiver market — based on the number of devices installed in the market — is cellular handsets, followed by general location and navigation ("GLN") devices.[12] Both of these categories of consumer devices are fully compatible with Ligado's proposed terrestrial operations.

- Only one out of the 12 consumer GLN devices tested showed any effect from Ligado's proposed operations under any conditions, and that effect was observed only when the device was in motion, was receiving impaired GPS signals, and when the LTE signal at the GPS device was above -30 dBm, an event that will occur with extremely low probability.[13]

- Similarly, "[a]ll three cellular devices tested (one tablet and two cell phones) maintained their baseline GPS position accuracy in the presence of Ligado's proposed operations," and "cellular GPS devices' performance, which already is highly robust, continues to improve."[14]

- Finally, the non-certified aviation device RAA tested maintained its baseline GPS position accuracy in the presence of Ligado's proposed operations, while industrial

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("December 8 Ex Parte"); Letter from Gerard J. Waldron, Counsel to New LightSquared LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 12- 340; IB Docket No. 11-109; IBFS File Nos. SAT-MOD-20101118-00239; SAT-MOD-20120928- 00160; SAT-MOD-20120928-00161; SES-MOD-20121001-00872; SES-RWL-20110908-01047; SES-MOD-20141030-00835, at 25 (Dec. 17, 2015) ("December 17 Ex Parte"); Letter from Gerard J. Waldron, Counsel to New LightSquared LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 12-340; IB Docket No. 11-109; IBFS File Nos. SES-MOD- 20151231-00981, SAT-MOD-20151231-00090, and SAT-MOD-20151231-00091, at 4, 7, 19 (Feb. 3, 2016) ("February 3 Ex Parte").

[11] Roberson and Associates, LLC, "Final Report: GPS and Adjacent Band Co-Existence Study," IB Docket No. 11-109, at 16 (filed June 10, 2016) ("Roberson Final Report"). Ligado previously filed RAA's results and accompanying data on May 11, 2016. *See* Roberson and Associates, LLC, "Results of GPS and Adjacent Band Co-Existence Study," IB Docket No. 11-109 (filed May 11, 2016) ("Roberson Results Report"). The Roberson Final Report expands on the Roberson Results Report with additional details regarding the testing process and analysis. Ligado also has filed the detailed dataset underlying the testing, which includes the detailed listings of the position errors used to produce the Key Performance Indicator graphs shown in the Roberson Results Report. *See* Letter from Gerard J. Waldron, Counsel to Ligado Networks, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 *et al.* (filed June 7, 2016).

[12] *See* Bazelon Report, *supra* n.5, at 26 fig. 6 (May 23, 2016).

[13] Roberson Final Report at 16.

[14] *Id*.

> high-precision devices — as more fully described in Section III below — either experienced no impact or can be readily remedied to ensure no impact.[15]

These empirical results, in combination with the judgments reflected in the independent decisions by Garmin, Deere, and Trimble to enter into the Co-Existence Agreements, demonstrate that Ligado's proposed operations are compatible with GPS.

B. Grant of the Modification Applications Will Promote 5G, Enabling IoT and Other Innovative Applications, by Deploying Greenfield Spectrum.

As Ligado previously explained, American leadership in the emerging 5G environment requires efficient use of all types of spectrum.[16] Commissioner O'Rielly recently noted that 5G "will not operate in any particular spectrum band, but will use low, medium and high bands."[17] Greenfield, nationwide mid-band spectrum like Ligado's plays a critical role given its potential to provide capacity and flexibility for the growing demand in next-generation IoT. The capacity and spectrum characteristics of this mid-band spectrum will complement the low-band spectrum that is being made available through the Incentive Auction by enabling collaboration that takes advantage of both bands. Granting the Modification Applications thus would promote 5G because Ligado's proposal is directly aligned with making possible these efficient uses of mid-band spectrum as part of the next generation of mobile networks.[18] In addition to fostering 5G and the tremendous potential benefits that the next generation of mobile connectivity has to offer, the Modification Applications will create between $250 billion and $500 billion of social

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[15] *See id*. at 17.

[16] Ligado Comments at 5-6.

[17] Remarks of Michael O'Rielly, FCC Commissioner, Before Hogan Lovells' Technology Forum: "The 5G Triangle," May 25, 2016, *available at* http://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0525/DOC-339558A1.pdf.

[18] *See* Bazelon Report, *supra* note 5, at 1.

welfare simply by alleviating enormous pent-up demand for wireless broadband service, which is currently the highest valued commercial use of spectrum.[19]

Other commenters recognize the strong public interest in facilitating the productive use of Ligado's mid-band spectrum. Public Knowledge notes that "[a]pproval of Ligado's applications will ensure that this valuable L-band spectrum does not lie fallow, which is particularly critical as consumers continue to adopt more bandwidth intensive uses of mobile broadband services."[20] Likewise, ViaSat explains that "the availability of hybrid satellite-terrestrial technologies in the L band … would create significant opportunities in both the data communications space and the positioning, navigation, and timing ('PNT') space," and that "such technologies could be leveraged to ensure ubiquitous network coverage, facilitating the availability of voice and data service throughout the United States and encouraging innovation in PNT applications and technologies."[21] And the Competitive Carriers Association notes that "Ligado's mid-band spectrum is well-positioned to play a critical role, among others, in both the development and advancement of 5G" by "mak[ing] 30 MHz of spectrum immediately available on a nationwide basis to support the transition to next-generation communications networks."[22] GPS

[19] *Id.* at 5, 8-9. The total social value of wireless broadband spectrum is estimated to be at least 10 to 20 times the direct economic value of the spectrum, and therefore approximately $250 billion to $500 billion of social welfare will be created by granting the Modification Applications. *Id*. at 8-9.

[20] Comments of Public Knowledge, New America's Open Technology Institute, and Common Cause, IB Docket Nos. 11-109 and 12-340, at 3 (filed May 23, 2016) ("Public Knowledge Comments").

[21] Comments of ViaSat, Inc., IB Docket No. 11-109 *et al.*, at 3 (filed May 23, 2016).

[22] Comments of Competitive Carriers Association, IB Docket Nos. 11-109 and 12-340, at 3 (filed May 23, 2016) ("CCA Comments").

manufacturers[23] and users[24] also recognize the public interest benefit of enabling further broadband deployment.

III. REMAINING CONCERNS RAISED BY SATELLITE AND CERTAIN INDUSTRIAL GPS STAKEHOLDERS ARE READILY ADDRESSED

A. The Satellite Industry's Concerns Have Been, or Can Be, Resolved.

The remaining concerns raised by satellite industry stakeholders can be — and are being — effectively resolved through ongoing cooperation between these stakeholders and Ligado. Ligado has demonstrated both its commitment and ability to reach practical solutions that address incumbent users' reasonable concerns while enabling the efficient and innovative use of Ligado's spectrum. Ligado's dedication to pragmatic problem-solving is reflected in the Co-Existence Agreements and in the more recently concluded coordination agreement between Ligado and the Aerospace and Flight Test Radio Coordinating Council with respect to protections for aeronautical mobile telemetry.[25] Ligado has taken the same approach to questions raised by the satellite industry.

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[23] *See* Comments of Garmin International, Inc., IB Docket 11-109 *et al.*, at i (filed May 23, 2016) ("Garmin has consistently supported the expansion of broadband services in this country."); Comments of Trimble Navigation Limited, IB Docket No. 11-109 *et al.*, at 2 (filed May 23, 2016) ("Trimble Comments") ("Taken as a whole, the Agreed Licensing Conditions represent a compromise which balances the competing public policy interests raised by Ligado's (and its predecessors') proposed use of their licensed spectrum. Given this compromise and balance, Trimble believes that it is in the public interest to grant the Modification Applications based upon the adoption of the Agreed Licensing Conditions as an integrated package.").

[24] *See* Comments of UNAVCO, IB Docket No. 12-340 (filed May 23, 2016) ("UNAVCO Comments") (acknowledging "nationwide availability of Wireless Broadband Internet is an important goal for the future of our nation").

[25] Letter from Dan Robinson, President, AFTRCC, and Jeffrey Carlisle, Executive Vice President for Regulatory Affairs, Ligado Networks LLC, to Marlene H. Dortch, Secretary, FCC, IB Docket Nos. 11-109 & 12-340 (filed May 23, 2016). Ligado recognizes that this letter applies only to AMT and not to GPS more generally, and that AFTRCC was not addressing any impact on GPS devices; Ligado's Reply Comments at p. 13 should not be interpreted as suggesting otherwise.

As Iridium notes, "Iridium and Ligado have engaged in discussions to try to develop a mutually agreed upon set of operational parameters" to address Iridium's concerns and "are working in good faith" toward such a resolution.[26] Since Iridium filed its comments in this proceeding, Ligado has been engaging in discussions with Iridium regarding the basis for Iridium's questions. The basis for Iridium's concerns is not yet entirely clear, given that Ligado's Modification Applications do not propose any change to Ligado's long standing, licensed operating parameters that could adversely affect Iridium. In fact, to the extent Iridium is concerned about out-of-band emissions limits, Ligado has proposed to substantially decrease its OOBEs below the level required by applicable FCC regulations[27] as part of its settlements with Garmin, Deere, and Trimble, which would make the radiofrequency environment even more benign than the one Iridium should have anticipated and would benefit Iridium by reducing emissions in its Big LEO band. Discussions with Iridium continue and both parties are committed to finding a mutually acceptable solution.

In addition, Boeing raised questions about the transition of any Inmarsat transceivers that could be affected by a future Ligado deployment.[28] Ligado, Boeing and Inmarsat have agreed to collaborate in an effort to resolve these issues.

B. Other Commenters Provide No Evidence Suggesting the Modification Applications Will Cause Harmful Interference to Industrial GPS Devices.

Finally, a few parties raise generalized concerns about the potential effect of Ligado's terrestrial operations, particularly on industrial high-precision GPS devices.[29] However, these

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[26] Comments of Iridium Communications, IB Docket No. 11-109 *et al.*, at 2-3 (filed May 23, 2016).

[27] *See* 47 C.F.R. § 25.202.

[28] Comments of The Boeing Company, IB Docket No. 11-109 *et al.*, at 2-3 (filed May 23, 2016).

[29] *See* UNAVCO Comments at 1; Comments of Resilient Navigation and Timing Foundation, IB Docket No. 11-109, at 1, 4 (filed May 23, 2016); Letter from Nikolaos Papadopoulos, President,

commenters fail to provide any "specific relevant technical information about affected GPS receivers (*e.g.*, receiver category, receiver bandwidth) and their performance or functioning (*e.g.*, break lock, loss of tracking, specific effects on location and timing accuracy) that support their assertion that additional measures would be necessary to resolve remaining concerns of potential harmful interference," as the Public Notice requested.[30] One commenter, u-blox, did present data purporting to show the "in-band jamming levels" of certain of its OEM GNSS receiver components when used with a passive, entirely unfiltered antenna.[31] But u-blox's cursory presentation — taking up less than two pages — provides no information about what the purported "jamming level" means in terms of actual device performance, nor does u-blox explain how it performed its calculations. In light of the data collected by RAA and submitted in this proceeding, Ligado is of the view that the issues raised by u-blox can be resolved through the same type of coordination that has resulted in the resolution of the concerns of other GPS companies.

Notably, the generalized concerns raised by these commenters conflict with the conclusion reached by Trimble, a leading provider of high-precision GPS receivers, that "[i]n light of the compromise and balance struck by the settlement agreements, Trimble believes that it is in the public interest to grant the Modification Applications consistent with the Agreed Licensing Conditions as an integrated package."[32] The generalized concerns raised by some

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u-Blox America, Inc., IB Docket 11-109 (filed June 15, 2016) ("u-blox Second Response"); Letter from Nikolaos Papadopoulos, President, u-Blox America, Inc., IB Docket No. 11-109, at 1-2 (filed May 20, 2016); Letter from Timothy St. J. Ellam, Counsel to NovAtel Inc., to Marlene H. Dortch, Secretary, FCC, IB Docket No. 11-109 *et al.*, at 3-4 (filed May 19, 2016) ("NovAtel Letter").

[30] Public Notice at 8.

[31] *See* u-blox Second Response, *supra* n.29, at 1-2.

[32] Trimble Comments at 2.

parties also conflict with the empirical results of RAA's testing. RAA found that, of 11 high-precision devices tested, four were unaffected by Ligado's proposed operations even when the devices were tested in stock condition, and any impact on three other devices was resolved by replacing the device's stock antenna with a filtered antenna. Of the remaining four devices, three Topcon devices were affected only in the 1526-1536 MHz band, but that effect does not account for the significantly lower power levels under which Ligado would operate in deference to current and future MOPS (Minimum Operational Performance Standards) that are incorporated into an active FAA Technical Standard Order (as detailed in Ligado's June 6 filing).[33] As Topcon notes, Ligado and Topcon "are engaged in productive discussions and working cooperatively to address Topcon's concerns."[34] Ligado also is in active discussions with NovAtel, the manufacturer of the remaining high-precision device.

Ligado's demonstrated success in working cooperatively with stakeholders provides assurance that any remaining concerns can be effectively addressed through good faith engagement by parties committed to reaching practical solutions. The Commission should encourage this type of pragmatic problem-solving, rather than acceding to some parties' demands that operations by licensees of spectrum adjacent to GPS be limited by technical criteria

[33] UNAVCO thus errs in its assertion that RAA's tests "showed that all types of GPS devices were severely affected by Ligado's proposed terrestrial MSS broadcasts, especially the newest state-of the art high-precision receivers." UNAVCO Comments. To the contrary, RAA's results show that Ligado's proposed terrestrial operation does not affect consumer devices and is compatible with high-precision devices, with any remaining concern readily amenable to resolution through good-faith coordination among interested parties.

[34] Comments of Topcon Positioning Systems, Inc., IB Docket Nos. 11-109 and 12-340, at 2 (filed May 23, 2016).

that have no relationship to whether these adjacent-band operations cause any harmful interference to GPS users.[35]

IV. CONCLUSION

The Commission now has a complete record that demonstrates granting the Modification Applications would serve the public interest by unlocking critical greenfield spectrum for 5G, enabling IoT and other innovative services, while at the same time ensuring the limitations negotiated by Deere, Garmin, and Trimble are codified and benefit the entire GPS industry. As the Competitive Carriers Association aptly notes, "Ligado has been working with key industry stakeholders and the Commission for over a decade to successfully conclude this rulemaking," and "[c]onsidering both the substance of the data on record and the length of time interested parties have been allotted to provide feedback, the instant proceeding is sufficient to fully resolve any outstanding issues and ultimately grant Ligado's request."[36] In light of the extensive data and analysis now available in the record, the Commission should promptly grant the Modification Applications.

[35] *See* Ligado Reply at 11-14. These parties, including NovAtel, argue that adjacent-band operations should be deemed to "harm" GPS if the operations cause a 1 dB degradation in the GPS receiver's carrier-to-noise density ratio (C/N_0). *See*, *e.g.*, NovAtel Letter at 2. As Ligado has demonstrated, however, changes in C/No are an unreliable indicator of impact to GPS key performance indicators. Notably, NovAtel itself made much the same point in its December 4, 2014, presentation to a Department of Transportation Workshop regarding the Department's Adjacent Band Compatibility Study, in which this high precision GPS device manufacturer stated clearly that it *"agreed that a 1 dB drop in CNo [sic] should not affect measurement or positioning accuracy." See* Attachment A hereto (emphasis added).

[36] CCA Comments at 3-4.

Respectfully submitted,

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Attachment

June 21, 2016

Attachment A

Applicable Testing and Associated Challenges

Sandy Kennedy

Chief Engineer, Receiver Cards

Dec. 4, 2014

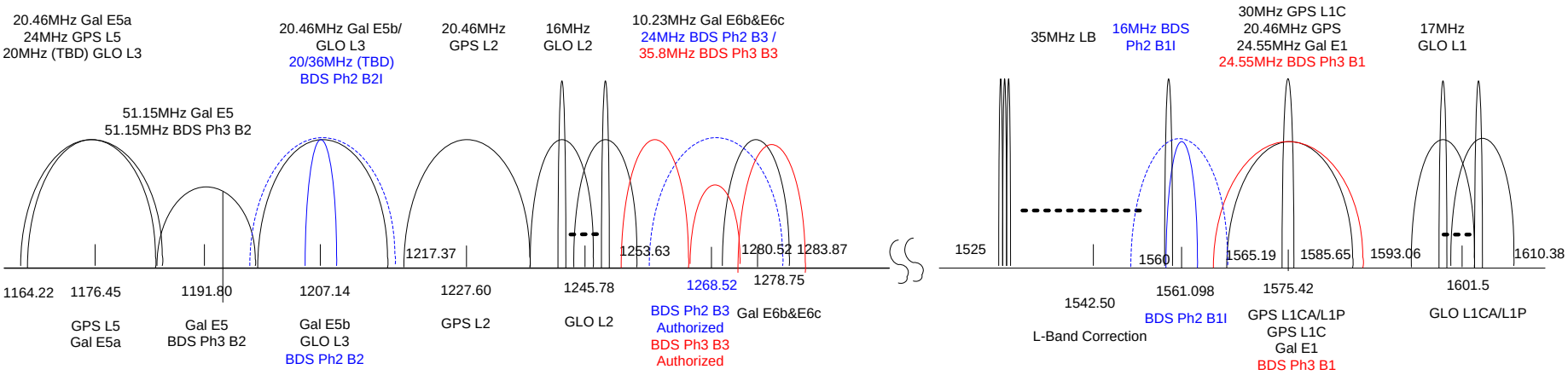
GPS ABC Workshop

Outline

- NovAtel Context
- Clarifications/Questions around standard definition
- Test Procedure questions/comments

NovAtel Context to Set 1 GPS L1 Only

- NovAtel receivers are wideband, at a minimum of 20MHz to adequately capture the full L1 CA main lobe
  - To achieve 4 cm code and 0.5 mm carrier phase measurements on GPS L1
- GPS L1 only users are typically a SW restricted on HW that is capable of multi-frequency and multi-constellations



Metric: SNR Degradation while Tracking

- Tracking vs Acquisition is key though
  - Acceptable delays in acquisition will depend on the application

- Is the intent worst case or nominal case?
  - Also very application dependent
  - 100% operation may be required for some, while intermittent drop outs okay for others

Threshold: 1 dB of CN

- Agreed that a 1 dB drop in CNo should not affect measurement or positioning accuracy
- Practical reliable measurement of 1 dB may be problematic
  - Perhaps measure 3 dB drop point and apply an offset to create a clean 1 dB drop line
- Mask reference point must be clear
  - Receiver input vs antenna LNA input
  - Active antenna typically used in high precision applications
  - Antenna element effect can be added as a correction

Interference Wave Form: CW

- Related to worst case vs nominal case
  - 5 MHz steps vs 1 kHz steps
  - Worst case is CW interference lined up with 1 KHz spacing of CA spectral lines
  - Chirp interferer has a higher probability of lining up with CA spectral lines
- Initial CW level must be well defined in test set up
  - As well as time between measurements to allow CNo to settle

Signal Scenario

- Simulator or Live?
  - Simulator is more repeatable/controllable
- 1 SV vs multiple SVs
  - 1 SV is easiest to define and set up
  - More grey areas with multiple SVs
    - Effect on positioning due to individual SVs being interfered with will depend on geometry
    - Number of SVs in view will depend on application, and specific of that applications
      - 9 SVs reasonable in some places, in many other only 3 or 4 SVs is typical

Margin for the Mask?

- Test equipment accuracy

- Unit to unit variation of units under test